Oscilatoare sinusoidale

- Generatoare de semnale: sinusoidal, dreptunghiular, triunghiular, rampa, etc.

- Generare semnal sinusoidal, **retea selectiva in frecventa** in bucla de RP a unui amplificator: *oscilator armonic*

-Frecventa de oscilatie: f_0

-Amplitudinea oscilatiei: $\hat{V}_o$

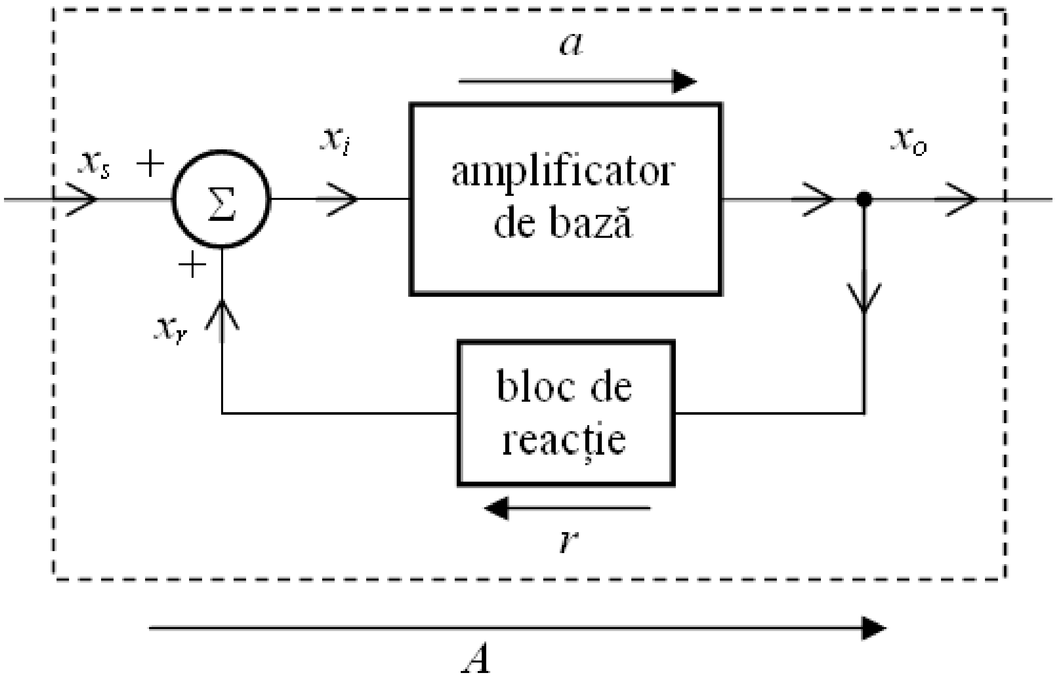
- Conditia de oscilatie, amorsare a oscilatiei

-Stabilitatea frecventei de oscilatie

-Stabilitatea amplitudinii

-Distorsiunea semnalului de iesire

Amplificator cu RP - reamintire



$$x_i = x_s + x_r$$

$$A = \frac{a}{1 - ar}$$

$$x_s = 0; \quad x_0 - \text{finit}$$

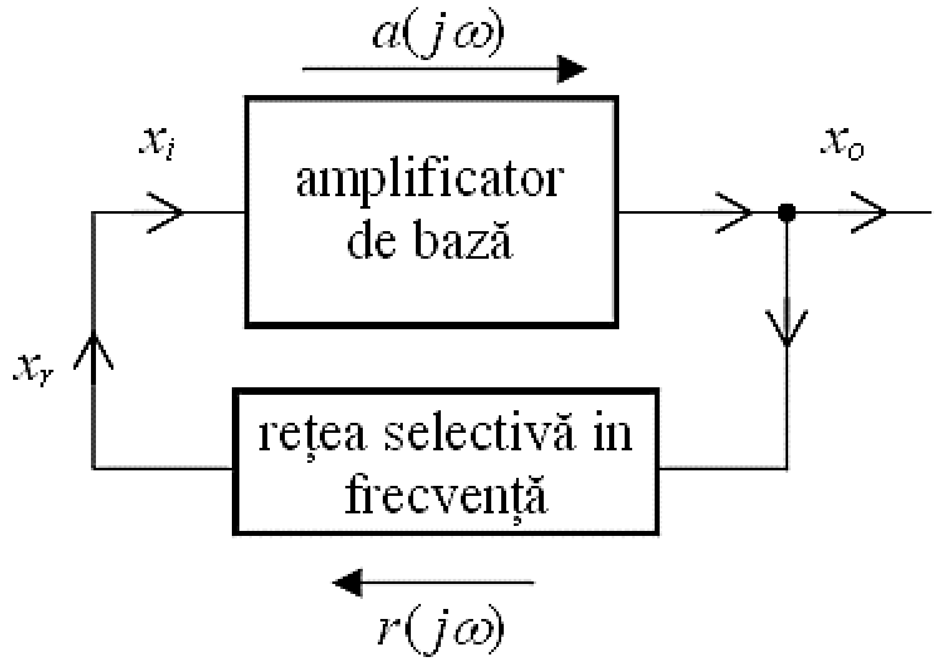
- Caz particular al RP:

$$(1 - ar) = 0; \quad ar = 1; \quad A \to \infty$$

$$x_o = Ax_s$$

x_o este finit numai daca x_s=0

Bucla de reacție



In domeniul complex

$$A(j\omega) = \frac{a(j\omega)}{1 - a(j\omega)r(j\omega)}$$

pentru o valoare unica $\omega_0 = 2\pi f_0$

$$1 - a(j\omega_0)r(j\omega_0) = 0$$

Condiția (criteriul) lui Barkhausen

$$\boxed{a(j\omega_0)r(j\omega_0) = 1}$$

condiţie de reconstructie a semnalului pe bucla

Componente cu comportarea dependenta de frecventa (*C*, *L*)

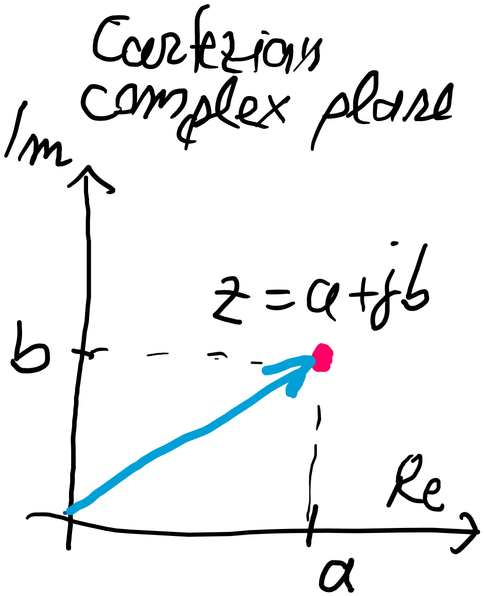
$$Zc = \frac{1}{j\omega C} = \frac{1}{j \cdot 2\pi f C}$$

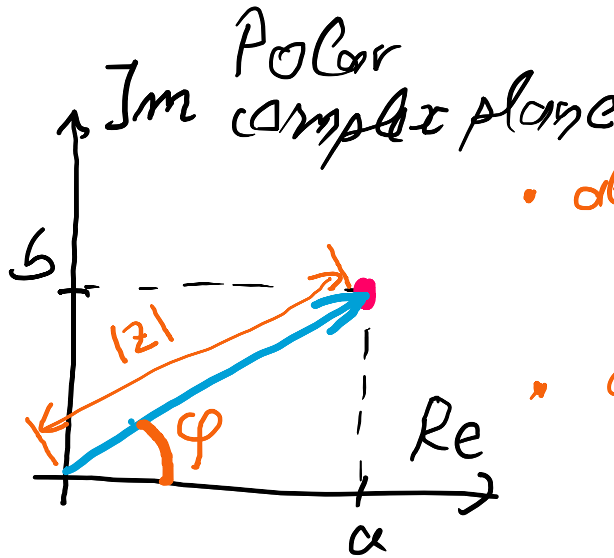
$$Z_L = j\omega L = j2\pi f L$$

Complex number - short review

$z = a + jb$ $\begin{cases} Re(z) = a \\ Im(z) = b \end{cases}$ $j = \sqrt{-1}$ imaginary unit

imaginary number





- absolute value; modulus:

  $|z| = \sqrt{a^2 + b^2}$ magnitude

- argument; phase

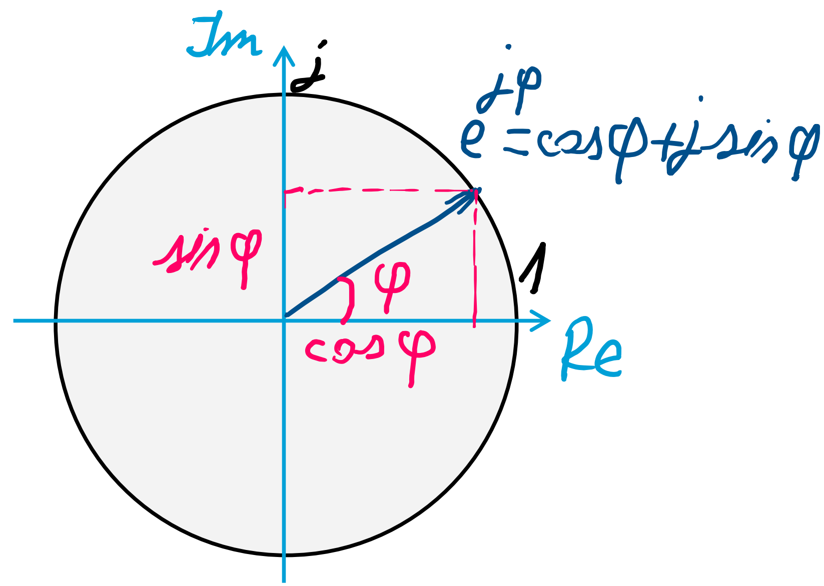
  $\varphi = \tan^{-1}\left(\frac{b}{a}\right)$

trigonometric form:

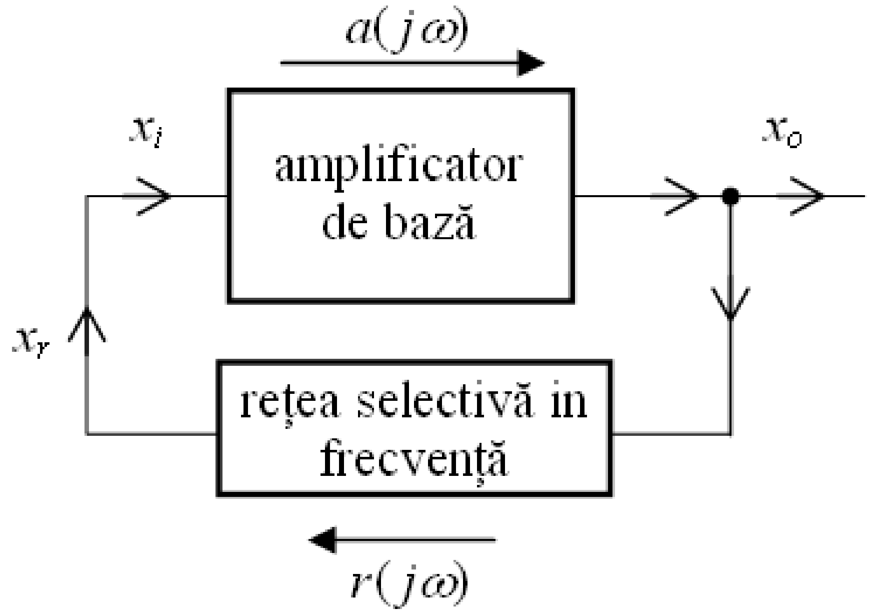
$z = |z| \cdot (\cos\varphi + j\sin\varphi)$

Euler's formula

$z = |z| e^{j\varphi}$



Condițiile de oscilație



$$a(j\omega) = |a(j\omega)| e^{j\varphi_a}$$

$$r(j\omega) = |r(j\omega)| e^{j\varphi_r}$$

$$a(j\omega_0) r(j\omega_0) = |a(j\omega_0)||r(j\omega_0)| e^{j(\varphi_a + \varphi_r)} = 1$$

condiţia de modul: $\boxed{|a(j\omega_0)||r(j\omega_0)| = 1}$ rezulta a_0

Amplificarea pe bucla este egala cu unitatea în valoare absolută

conditia de fază: $\boxed{\varphi_a + \varphi_r = 2k\pi}$ rezulta f_0

Defazajul pe bucla este zero sau un multiplu întreg de 2π

Oscilatoare RC

- **Amplificatorul de baza** independent de frecventa
  - inversor $\varphi_a = 180^o$
  - neinversor $\varphi_a = 0$

- **Retea de reactie** selectiva in frecventa

Pentru a indeplini conditia de faza, trebuie
sa existe o frecventa unica, *f*$_0$ la care defazajul introdus sa fie:

$$\varphi_r = 180^0, \quad \text{daca} \quad \varphi_a = 180^0$$

$$\varphi_r = 0^0, \quad \text{daca} \quad \varphi_a = 0^0$$

Oscilatoare RC

- **Amplificator de bază** independent de frecvență:
  - inversor $\varphi_a = 180^{o}$
  - neinversor $\varphi_a = 0$

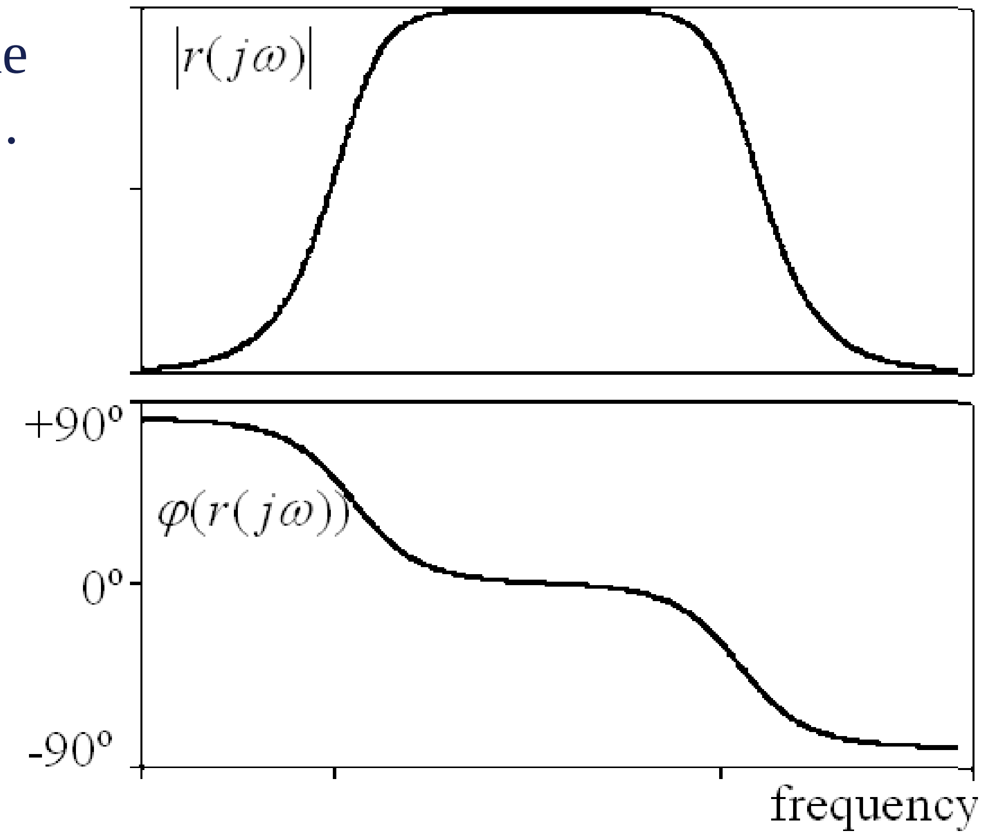
- **Rețea de reacție** selectiva in frecventa de tip trece banda

Defazajul introdus de reteaua de reactie este in domeniul [+90º; -90º].

Pentru a indeplini conditia de faza:

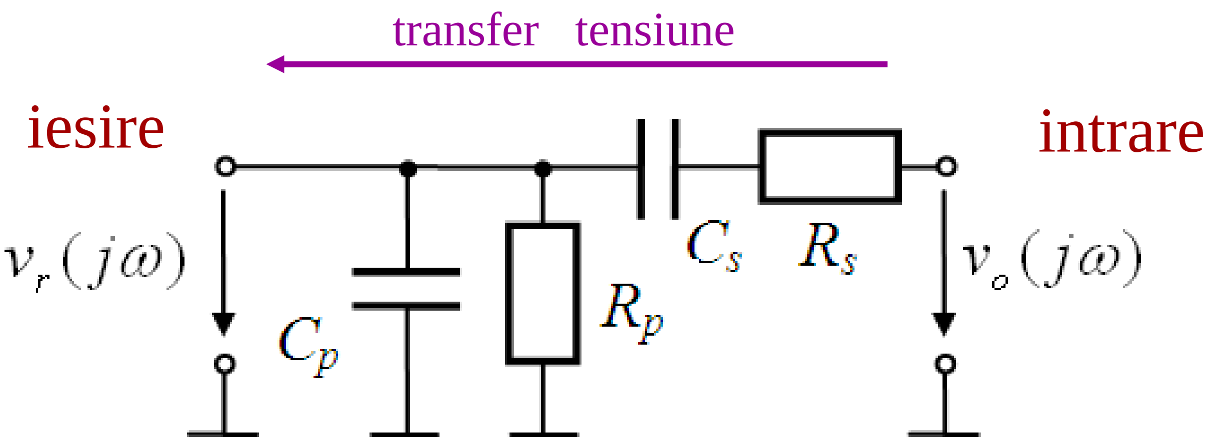
- amplificator neinversor
- $\varphi_r = 0$ pentru o frecventa unica (f_0)

Este necesar sa apropiem cei doi poli.



Puntea WIEN

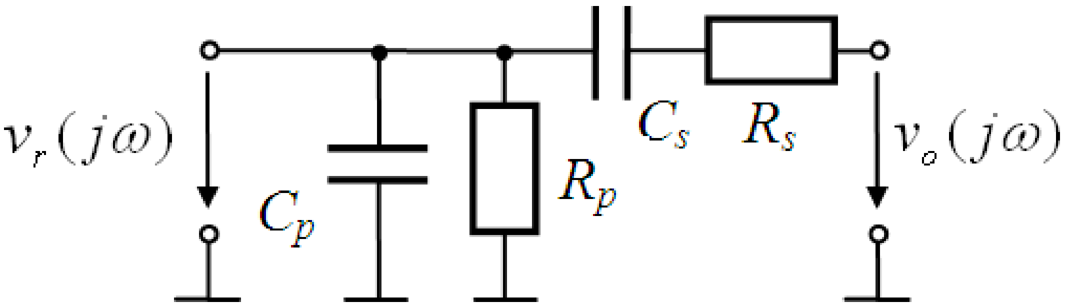
Circuit si functia de transfer complexa



$$v_r(j\omega) = r(j\omega)v_o(j\omega) \qquad r(j\omega) = \frac{v_r(j\omega)}{v_o(j\omega)}$$

$$r(j\omega) = \frac{Z_p}{Z_s + Z_p} \qquad Z_s = R_s + \frac{1}{j\omega C_s} \qquad Z_p = R_p \parallel \frac{1}{j\omega C_p}$$

$$r(j\omega) = \frac{v_r(j\omega)}{v_o(j\omega)} = \frac{1}{1 + \frac{R_s}{R_p} + \frac{C_p}{C_s} + j\left(\omega R_s C_p - \frac{1}{\omega R_p C_s}\right)}$$



Puntea WIEN

Modul si faza

$$r(j\omega) = \left|r(j\omega)\right| e^{j\varphi_r}$$

$$r(j\omega) = \frac{1}{1 + \frac{R_s}{R_p} + \frac{C_p}{C_s} + j\left(\omega R_s C_p - \frac{1}{\omega R_p C_s}\right)}$$

$$\left|r(j\omega)\right| = \frac{1}{\sqrt{\left(1 + \frac{R_s}{R_p} + \frac{C_p}{C_s}\right)^2 + \left(\omega R_s C_p - \frac{1}{\omega R_p C_s}\right)^2}}$$

Modul

Faza

$$\varphi_r = -arctg\left(\frac{\omega R_s C_p - \frac{1}{\omega R_p C_s}}{1 + \frac{R_s}{R_p} + \frac{C_p}{C_s}}\right)$$

Puntea WIEN

Modul

$$\left|r(j\omega)\right| = \frac{1}{\sqrt{\left(1+\frac{R_s}{R_p}+\frac{C_p}{C_s}\right)^2+\left(\omega R_s C_p-\frac{1}{\omega R_p C_s}\right)^2}}$$

$\omega \to 0$ $\quad$ $\left|r(j\omega)\right| \to 0$ $\quad$ asimptota

$\omega \to \infty$ $\quad$ $\left|r(j\omega)\right| \to 0$ $\quad$ asimptota

$$\omega = \omega_o = \frac{1}{\sqrt{R_s R_p C_s C_p}} \qquad \left|r(j\omega)\right| = \frac{1}{1+\frac{R_s}{R_p}+\frac{C_p}{C_s}}$$

valoarea maxima

Puntea WIEN

Faza

$$\varphi_r = -arctg\left(\frac{\omega R_s C_p - \dfrac{1}{\omega R_p C_s}}{1 + \dfrac{R_s}{R_p} + \dfrac{C_p}{C_s}}\right)$$

$\omega \to 0$ $\quad\varphi_r \to +90^0$ asimptota

$\omega \to \infty$ $\quad\varphi_r \to -90^0$ asimptota

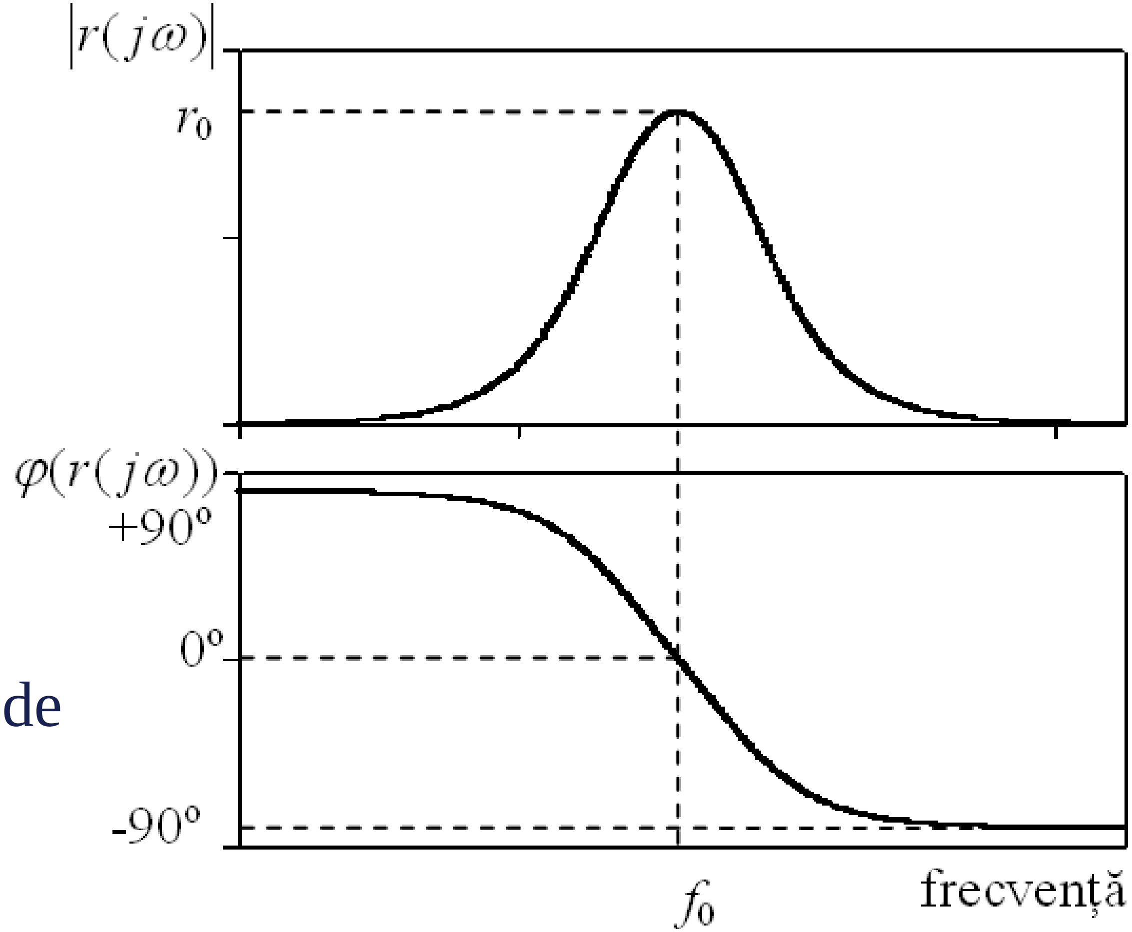
$$\omega = \omega_o = \frac{1}{\sqrt{R_s R_p C_s C_p}}$$ $\quad\varphi_r = 0^0$ valoare intermediara

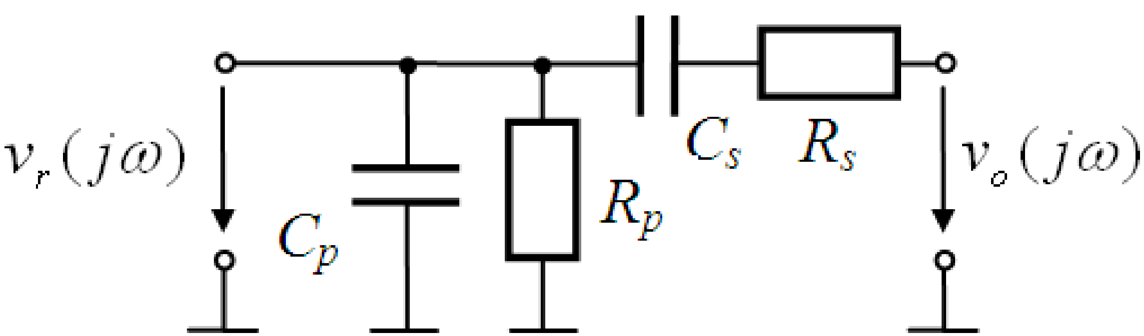
Puntea WIEN

pentru
o unică frecvenţă, f_0
avem

$$\varphi_r = 0$$

Pentru a indeplini conditia de faza: => amplif neinversor

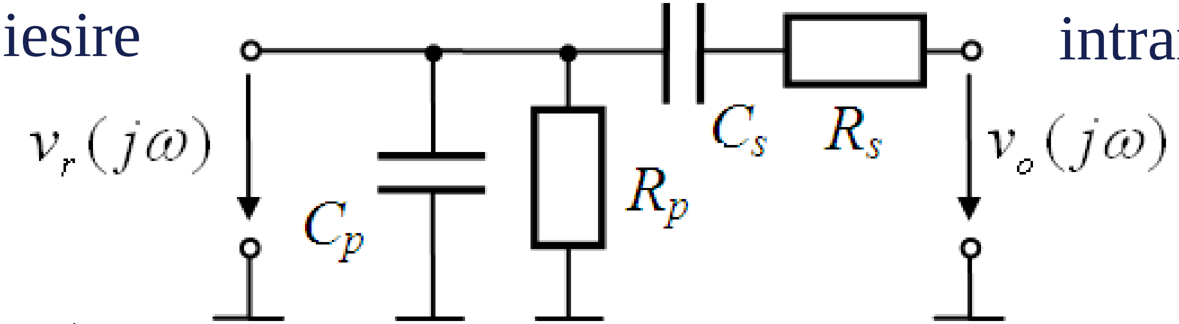




iesire

intrare

Puntea WIEN



$$r(j\omega) = \frac{v_r(j\omega)}{v_o(j\omega)} = \frac{1}{1 + \frac{R_s}{R_p} + \frac{C_p}{C_s} + j\left(\omega R_s C_p - \frac{1}{\omega R_p C_s}\right)}$$

$$\varphi_r = 0 \qquad \omega_0 R_s C_p - \frac{1}{\omega_0 R_p C_s} = 0 \qquad \omega_0 = \frac{1}{\sqrt{R_s R_p C_s C_p}}$$

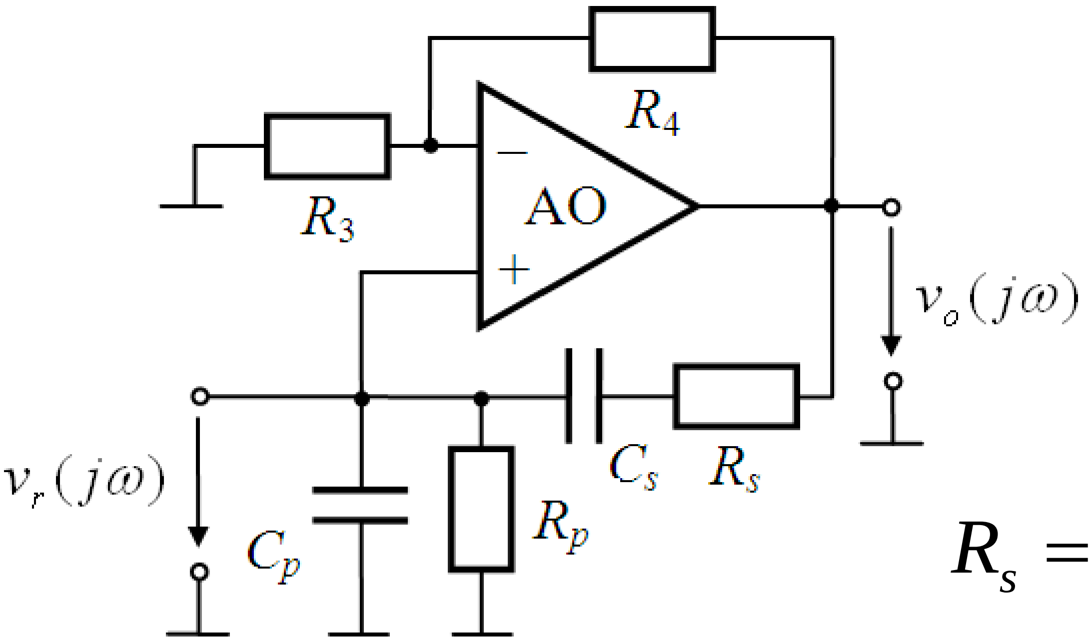
$$\boxed{f_0 = \frac{1}{2\pi\sqrt{R_s R_p C_s C_p}}} \qquad \boxed{\left|r(j\omega_0)\right| = \frac{1}{1 + \frac{R_s}{R_p} + \frac{C_p}{C_s}}}$$

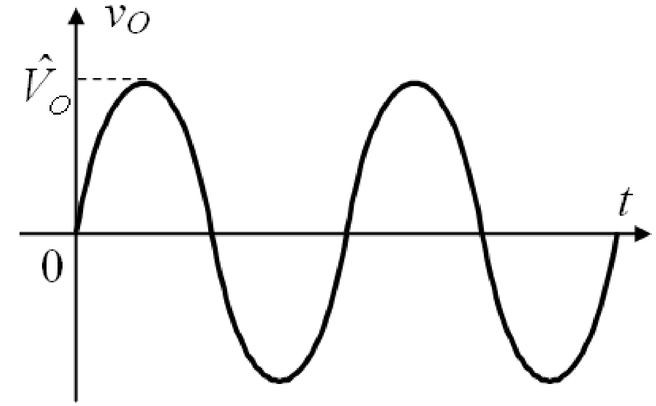
Dacă $R_s = R_p = R$

$C_s = C_p = C$

$$\boxed{f_0 = \frac{1}{2\pi RC}} \qquad \boxed{\left|r(j\omega_0)\right| = \frac{1}{3}}$$

Oscilator cu AO si punte WIEN





$$v_o(t) = \hat{V}_o \sin 2\pi f_0 t$$

$$R_s = R_p = R \qquad C_s = C_p = C$$

$$|a(j\omega_0)| = \frac{1}{|r(j\omega_0)|} = 3$$

$$\boxed{f_0 = \frac{1}{2\pi RC}} \qquad \boxed{|r(j\omega_0)| = \frac{1}{3}}$$

$$a = 1 + \frac{R_4}{R_3} \qquad 1 + \frac{R_4}{R_3} = 3 \qquad R_4 = 2R_3$$

$\hat{V}_o = ?$ Determinata de apropiere de saturatie a AO

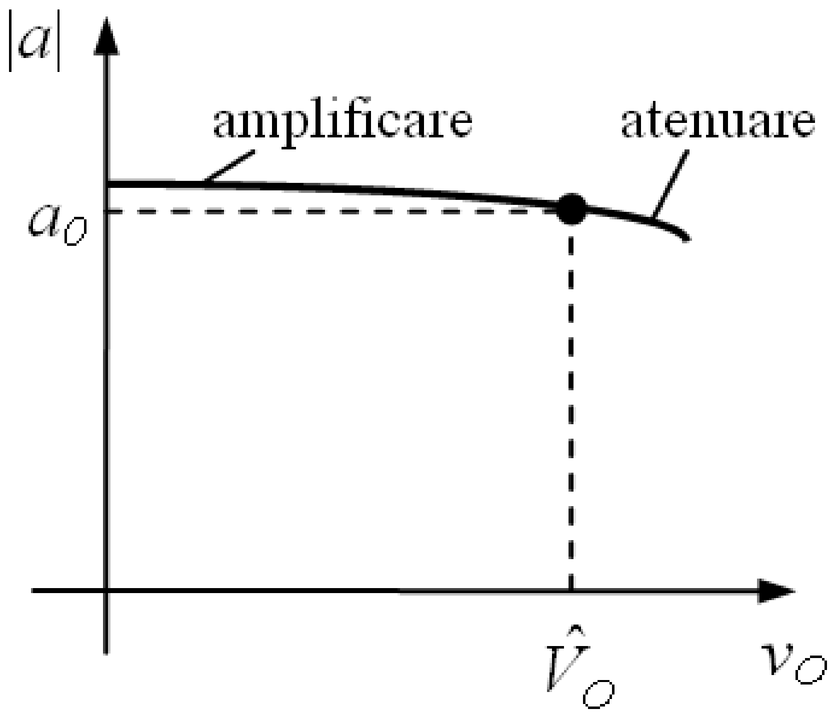
Controlul automat al amplificării (CAA)

$|a(j\omega)||r(j\omega)| < 1$ oscilaţiile sunt atenuate - zero

$|a(j\omega)||r(j\omega)| > 1$ oscilaţiile sunt amplificate - saturatie

$|a(j\omega_0)||r(j\omega_0)| = 1$ oscilațiile sunt menținute (întreținute)

Asigurarea stabilitatii amplitudinii de oscilatie: control automat al amplificarii depinzând de valoarea tensiuni de iesire $\hat{V}_o$

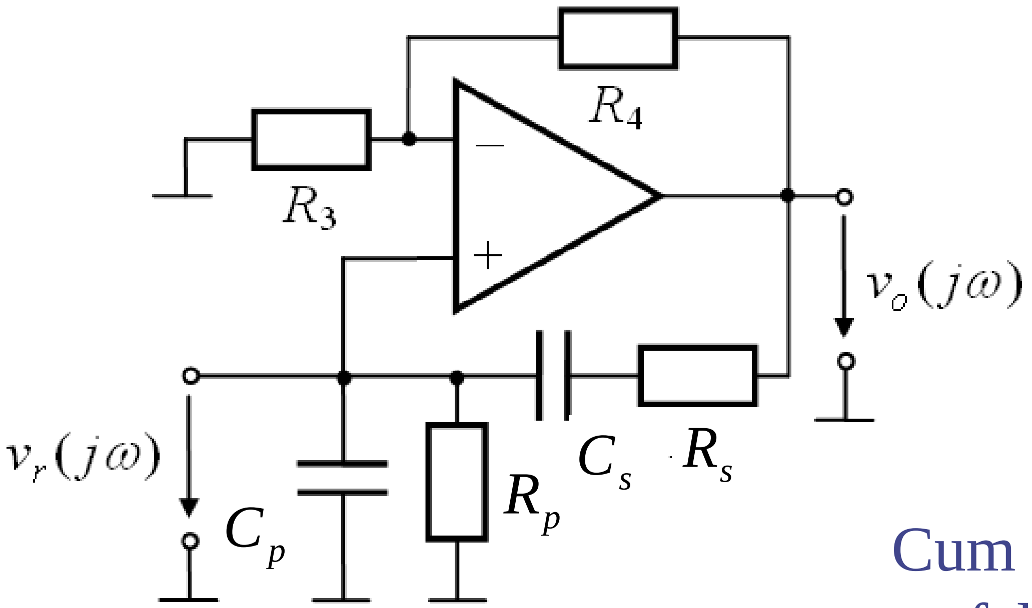


$$v_o = \hat{V}_o \sin 2\pi f_0 t$$

$$|r(j\omega)| = cst$$

$$\underline{\hat{V}_o \uparrow}, |a(j\omega_0)| \downarrow, \underline{\hat{V}_0 \downarrow}$$

CAA pentru oscilatorul cu punte Wien



$$a = 1 + \frac{R_4}{R_3}$$

Cum se poate implementa CAA astfel încât a să depindă de v_o?

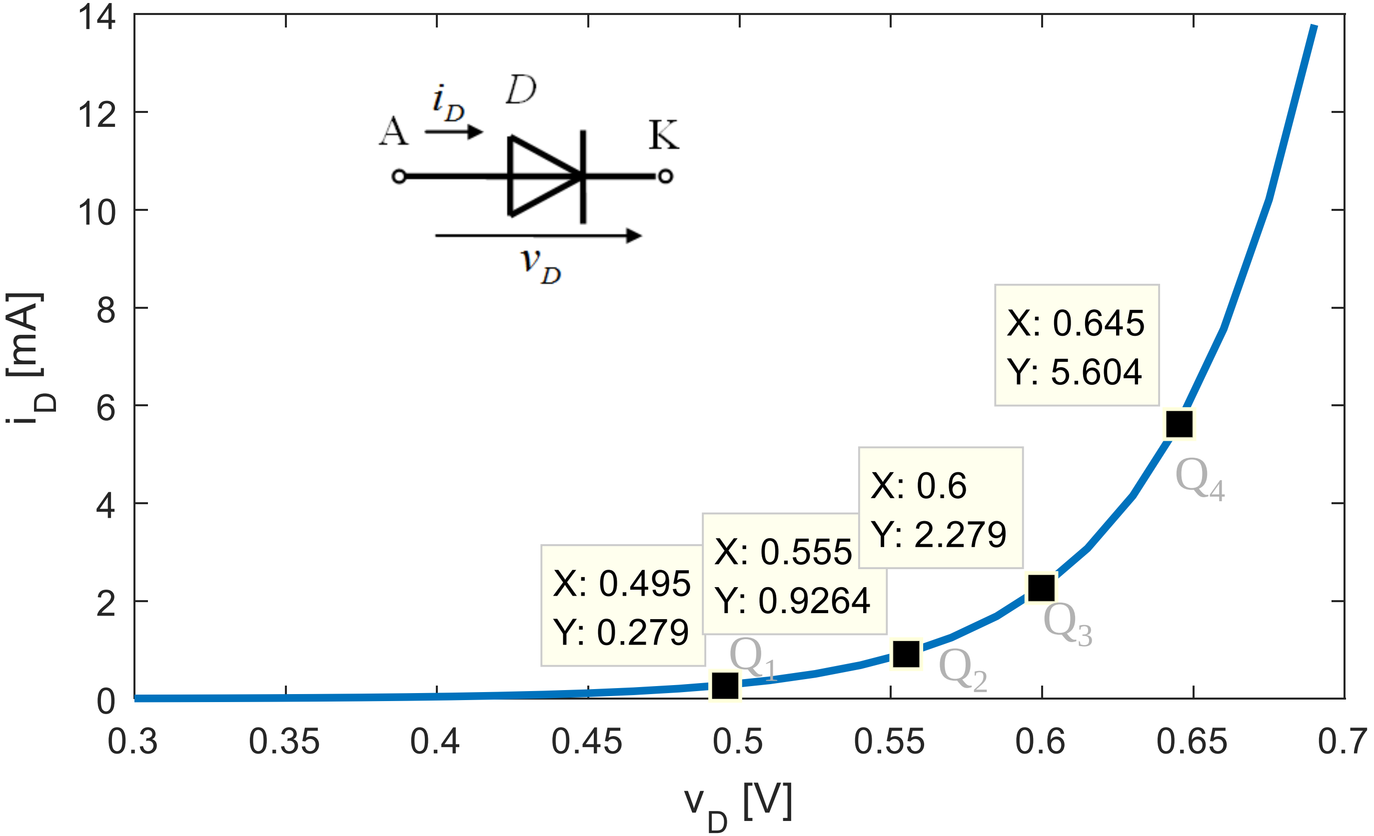
O rezistenta echivalenta sa depinda de tensiunea de iesire

- R_4 - să depindă de v_o

sau

- R_3 - să depindă de v_o

Dioda revizitata - rezistenta variabila



Rezistenta statica a diodei in PSF

$$r_D = \frac{V_D}{I_D}$$

$$r_{D1} = \frac{V_{D1}}{I_{D1}} = \frac{0.495\,\mathrm{V}}{0.279\,\mathrm{mA}} = 4.24\,\mathrm{k\Omega}$$

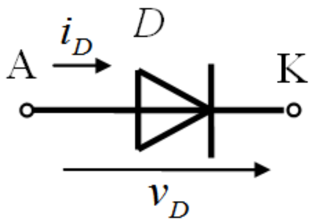
$$r_{D2} = \frac{V_{D2}}{I_{D2}} = \frac{0.555\,\mathrm{V}}{0.926\,\mathrm{mA}} = 0.599\,\mathrm{k\Omega}$$

$$r_{D3} = \frac{V_{D3}}{I_{D3}} = \frac{0.6\,\mathrm{V}}{2.279\,\mathrm{mA}} = 0.263\,\mathrm{k\Omega}$$

$$r_{D4} = \frac{V_{D4}}{I_{D4}} = \frac{0.645\,\mathrm{V}}{5.604\,\mathrm{mA}} = 0.115\,\mathrm{k\Omega}$$

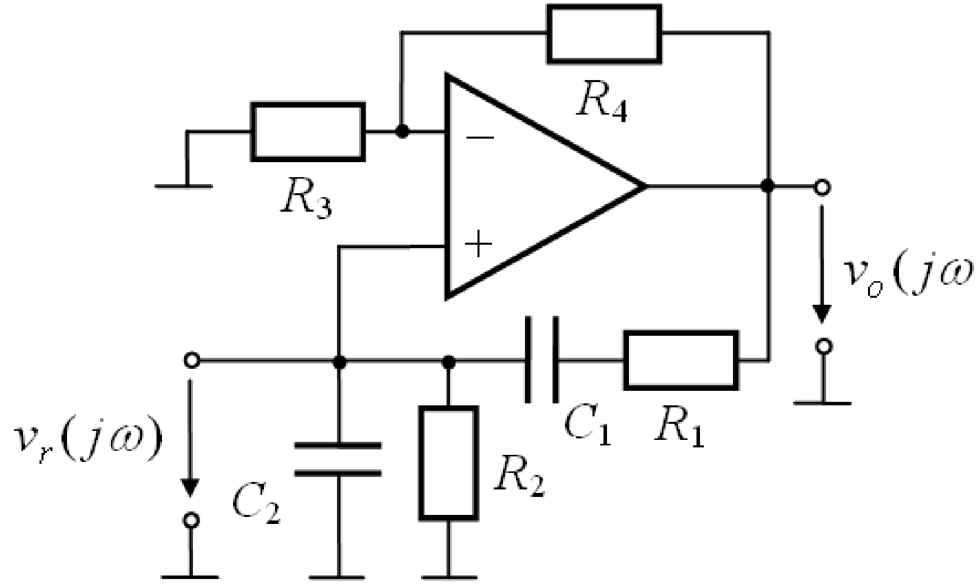
Daca V_D **creste**, atunci r_D **scade**

CAA al amplificarii - cum?



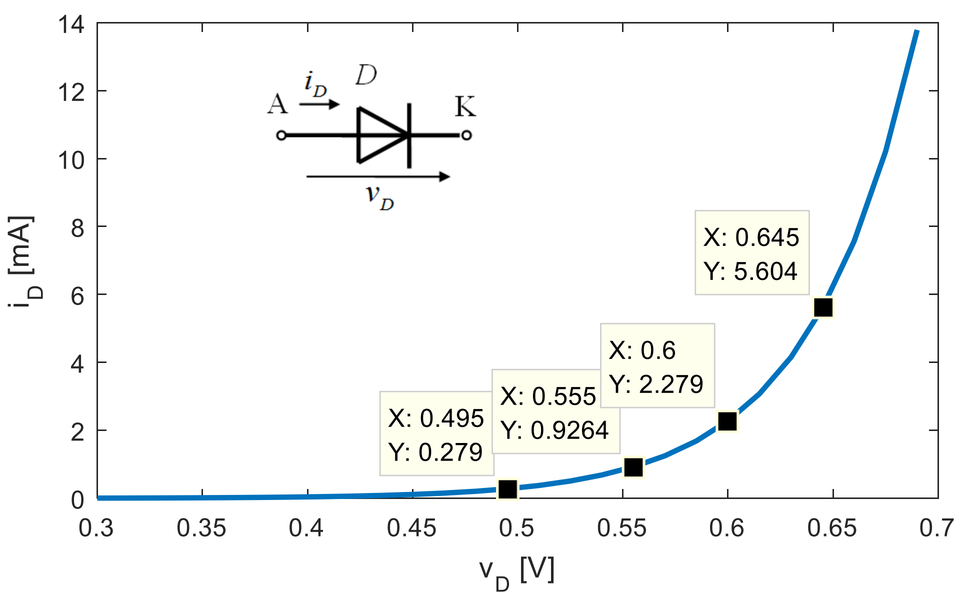
$$r_D = \frac{V_D}{I_D}$$

Daca V_D **creste**, atunci r_D **scade**



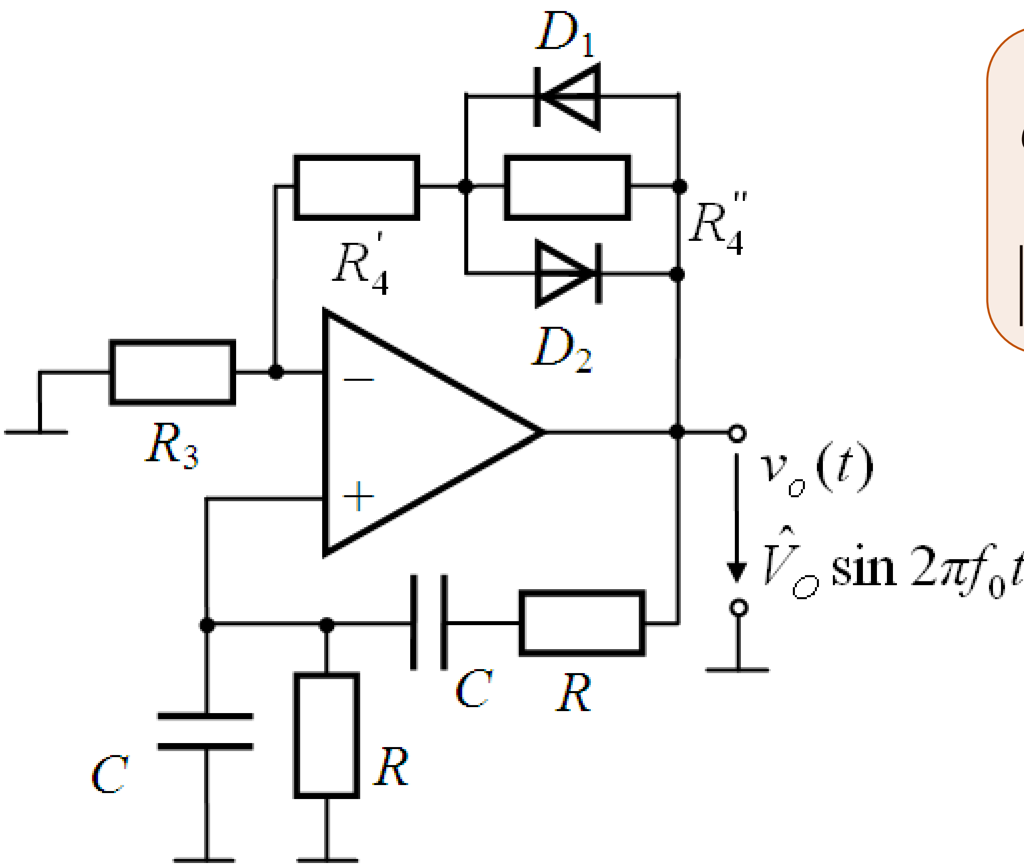
$$a = 1 + \frac{R_4}{R_3}$$

- R_4 - dependent de v_o



1. Cu diode

pentru $v_o(t)$ mică, D_1, $D_2 - (b)$



$$a_b = 1 + \frac{R_4' + R_4''}{R_3}$$

$$|a_b(j\omega_0)||r(j\omega_0)| > 1$$

$v_o(t)$ creşte, $D_1 - (c)$ pe alternanţa pozitivă

$D_2 - (c)$ pe alternanţa negativă

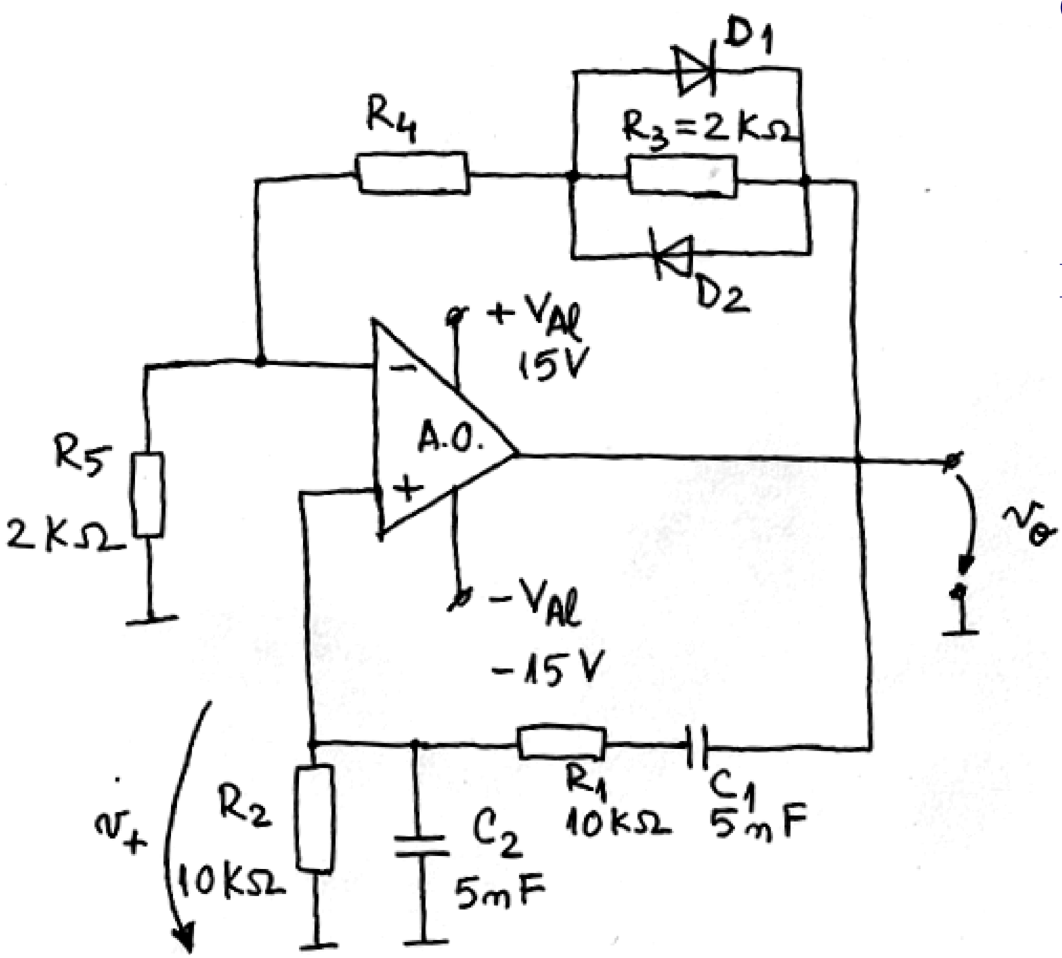
$$a_c = 1 + \frac{R_4' + R_4'' \parallel r_d}{R_3}$$

$$|a_c(j\omega_0)||r(j\omega_0)| = 1$$

mentinerea oscilatiilor

$\hat{V}_o$ data de valoarea r_d

Problema



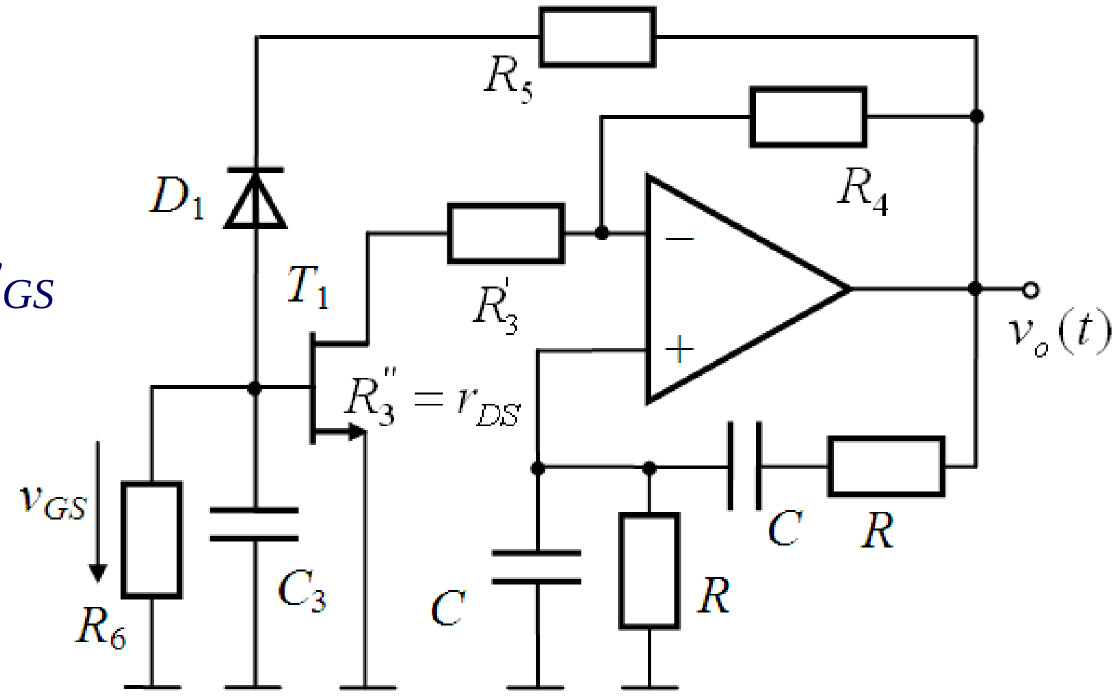
Cum arată, calitativ, semnalele $v_o(t)$ şi $v_+(t)$ în regim permanent? Calculaţi frecvenţa semnalului de ieşire $v_o(t)$.

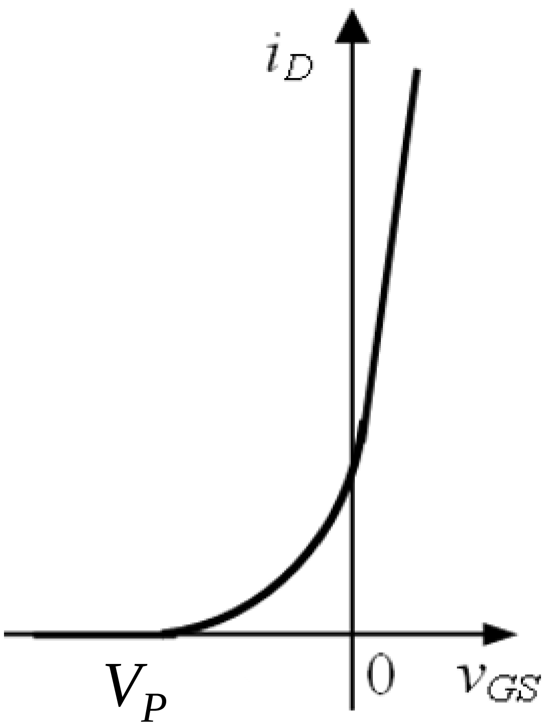
Dimensionaţi R_4 astfel încât circuitul să asigure menţinerea oscilaţiilor în regim permanent. Se va considera că în conducţie rezistenţa echivalenta a diodei este $r_{D1,on}=r_{D2,on}=0{,}5\ \text{K}\Omega$, iar in bocare $r_{D1,off}=r_{D2,off}=\infty$. Verificaţi că valoarea aleasă pentru R_4 permite şi amorsarea oscilaţiilor în regim tranzitoriu.

2. **Cu MOSFET cu canal inițial de tip *n***

r_{DS} - rezistență liniară comandată de tensiunea v_{GS}

$$a = 1 + \frac{R_4}{R_3^{'} + r_{DS}}$$

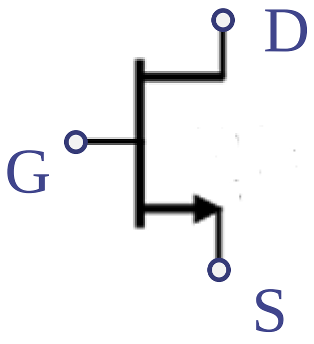


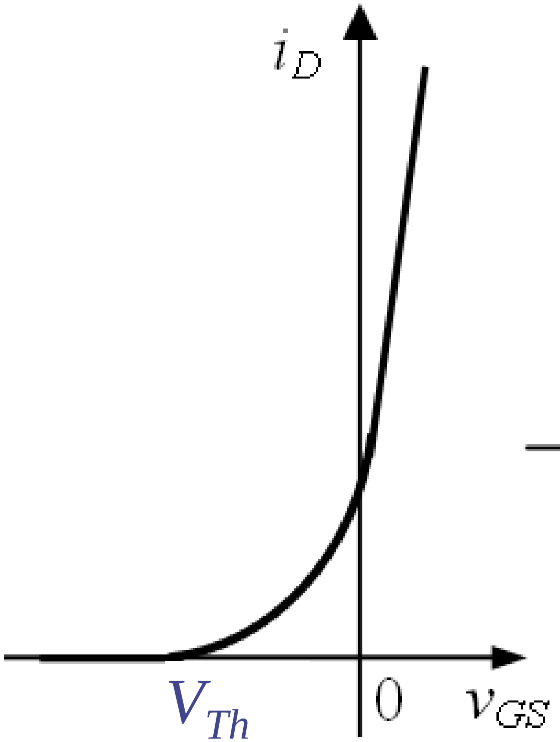


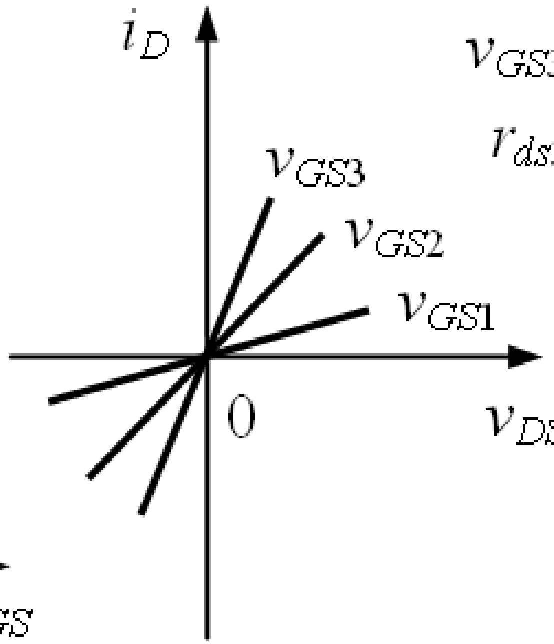
D_1, C_3 – detector de vârf negativ

T_1 funcționeaza cu $v_{GS} < 0$

MOSFET cu canal initial de tip *n* utilizat in regiunea liniara





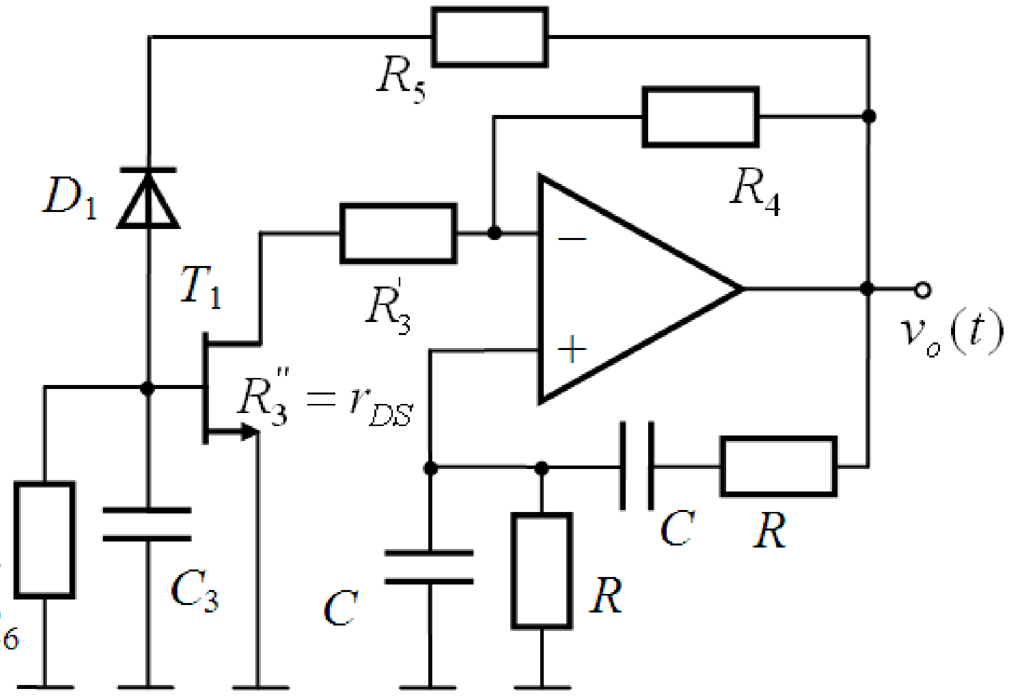


$$i_D = \beta\left[2\left(v_{GS} - v_{Th}\right)v_{DS} - v_{DS}^2\right]$$

Pentru v_{DS} mic

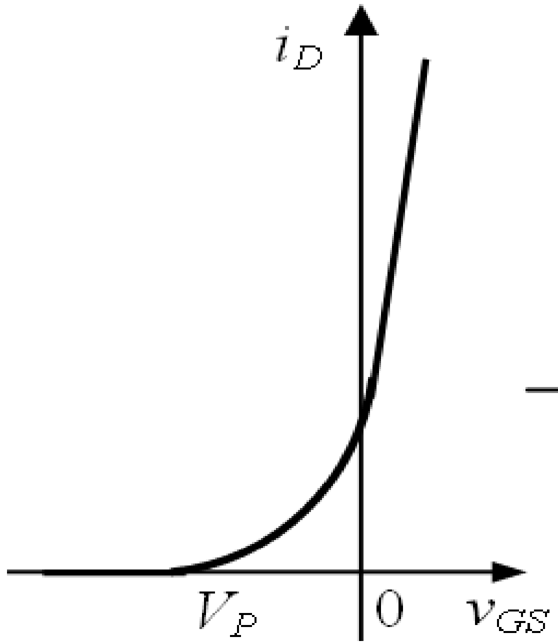
$$i_D \approx 2\beta\left(v_{GS} - v_{Th}\right)v_{DS} \qquad r_{DS} = \frac{v_{DS}}{i_{DS}} = \frac{1}{2\beta\left(v_{GS} - v_{Th}\right)}$$

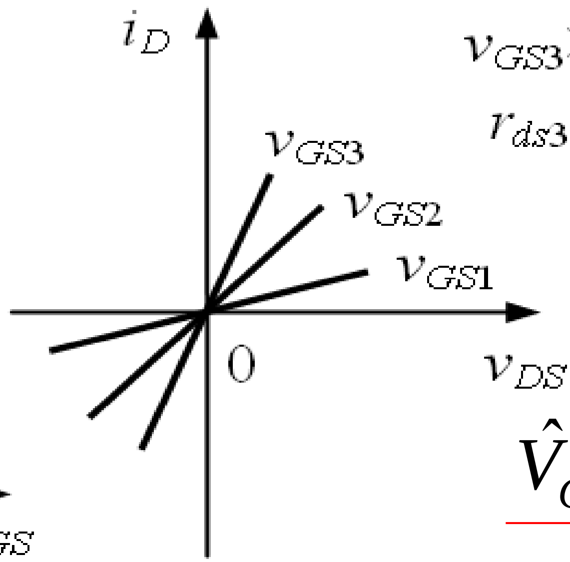
r_{DS} - rezistenta liniara comandata de tensiunea v_{GS}



$$a = 1 + \frac{R_4}{R_3^{'} + r_{DS}}$$

$$r_{DS} \approx \frac{1}{2\beta(v_{GS} - V_{Th})}$$





$v_{GS3} > v_{GS2} > v_{GS1}$

$r_{ds3} < r_{ds2} < r_{ds1}$

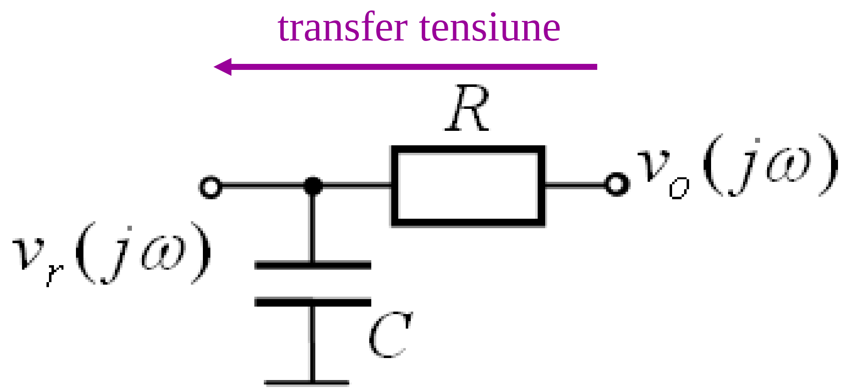
D_1, C_3 – detector de varf negativ

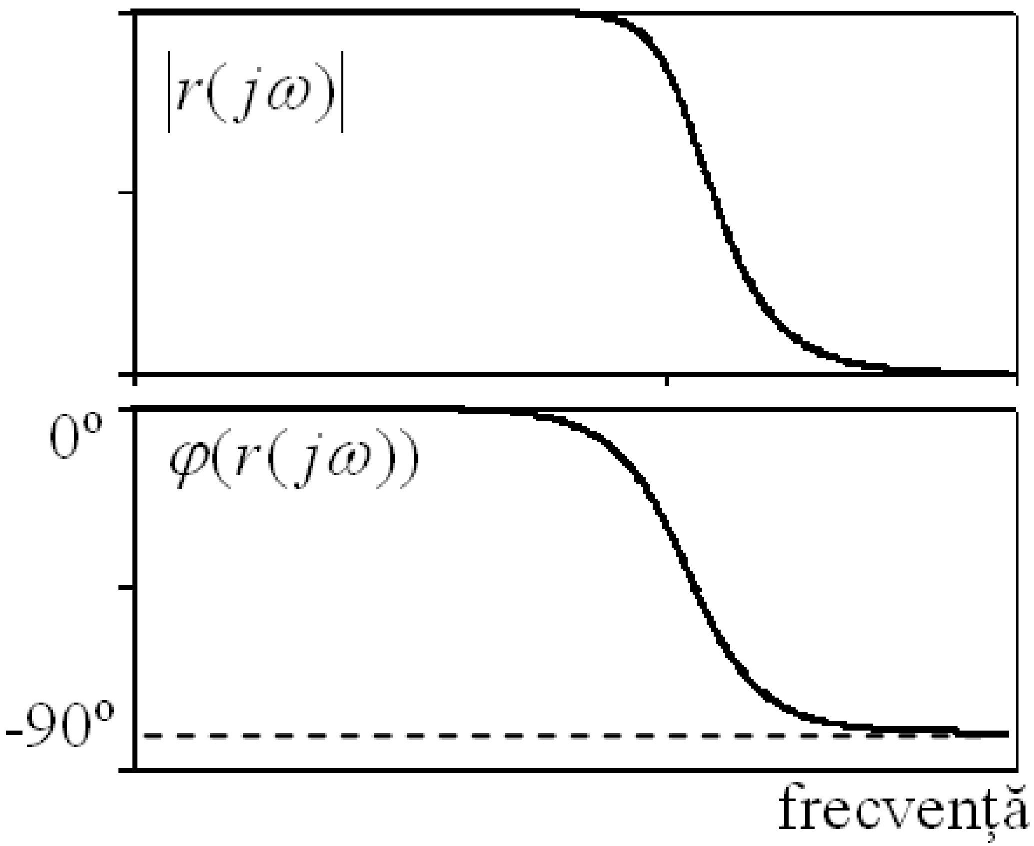
T_1 functioneaza cu $v_{GS} < 0$

$$\hat{V}_O \uparrow,\ v_{GS} \downarrow,\ r_{DS} \uparrow,\ a \downarrow,\ \hat{V}_O \downarrow$$

Oscilator cu AO și rețea defazoare RC

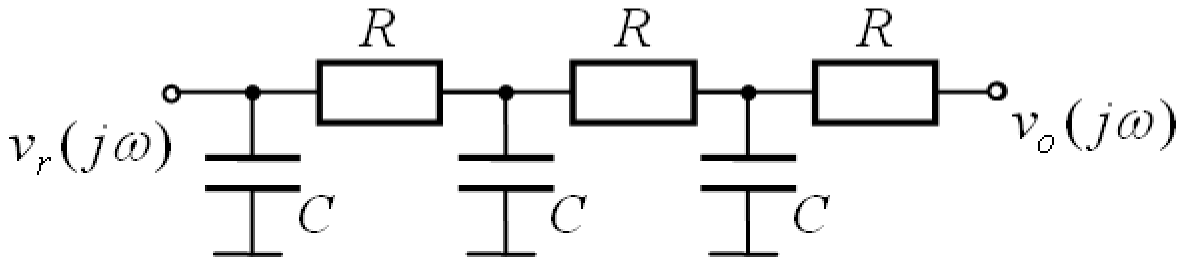
- Trece sus
- **Trece jos**





- defazajul rețelei de reacție este in domeniul [0^o; -90^o]
- amplificator de baza inversor
- care este numarul minim de celule RC de acelaşi fel pentru a putea construi un oscilator sinusoidal?

Retea defazoare RC trece jos cu trei celule



$$r(j\omega)=\frac{1}{1-5(\omega RC)^2+j\left[6\omega RC-(\omega RC)^3\right]}$$

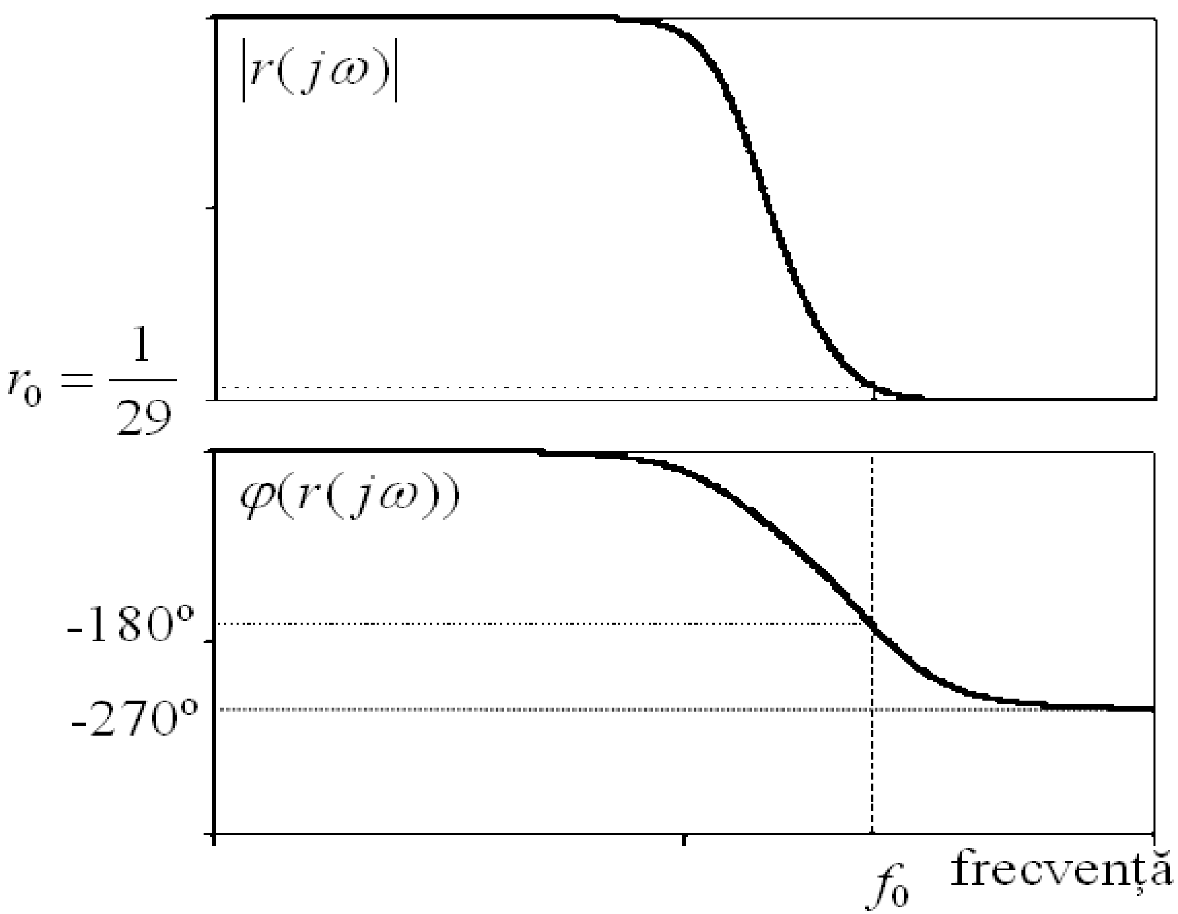
$$\varphi_r=-180^{\circ}$$

$$6\omega_0 RC-(\omega_0 RC)^3=0$$

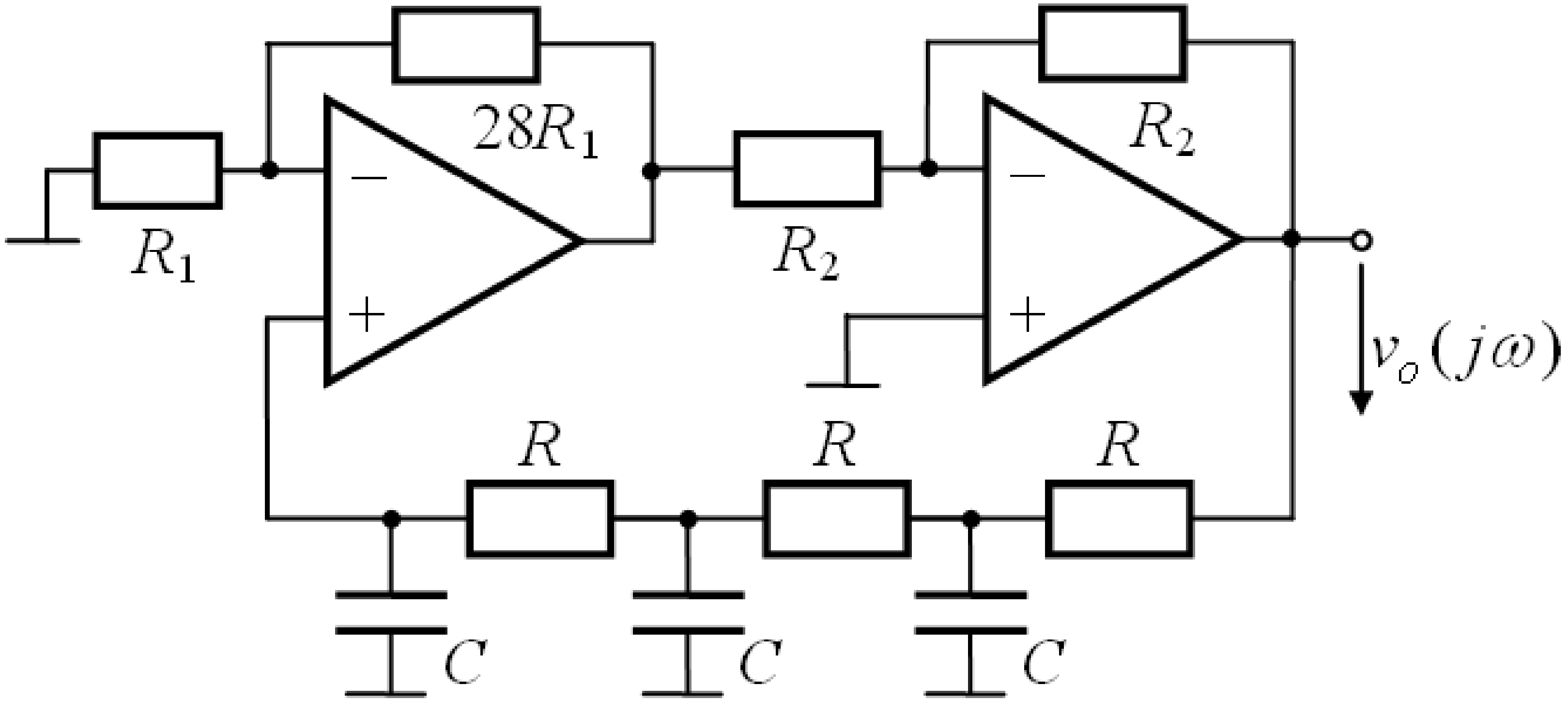
$$|r(j\omega_0)|=\frac{1}{29}$$

$$\boxed{f_0=\frac{\sqrt{6}}{2\pi RC}}$$

$$\boxed{r(j\omega_0)=-\frac{1}{29}}$$

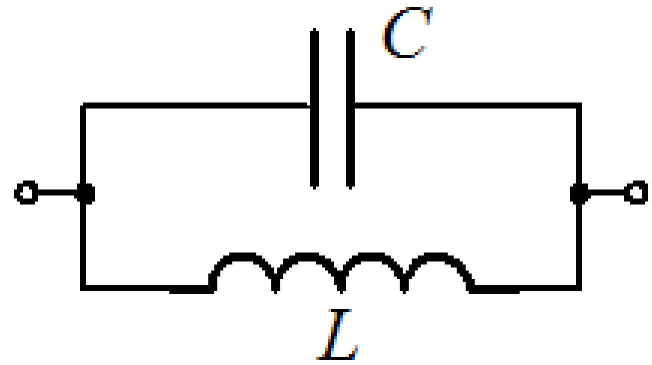


Schema oscilatorului cu AO
și rețea defazoare RC



De ce nu este utilizat un amplificator inversor cu un singur AO?

Oscilatoare LC



- circuit rezonant LC paralel
- se utilizează pentru frecvențe ridicate
- rețea de reacție selectivă în frecvență

$$Zech = Z_C \parallel Z_L \qquad Z_C = \frac{1}{j\omega C} \qquad Z_L = j\omega L$$

$$Zech = \frac{L/C}{j\left(\omega L - \frac{1}{\omega C}\right)}$$

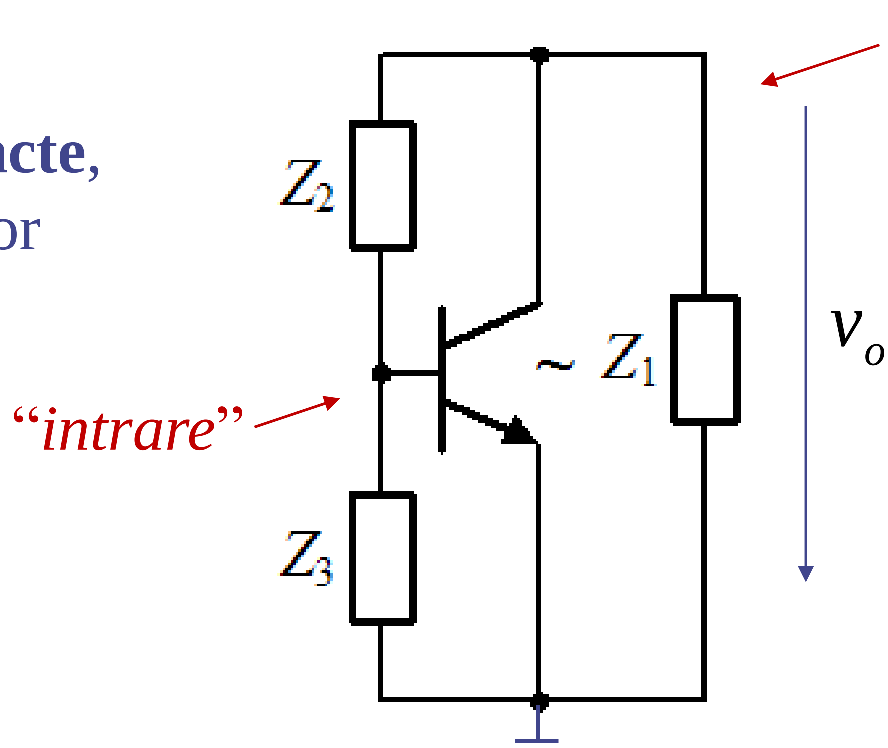
Frecvența de rezonanță:
Relația lui Thompson

$$\boxed{f_0 = \frac{1}{2\pi\sqrt{LC}}}$$

Circuitul LC paralel conectat in serie cu o sarcina funcționează ca un filtru oprește banda, având impedanța infinit la frecvența de rezonanță.

Cum se conecteaza circuitul LC paralel intr-un circuit cu RP pentru a rezulta un oscilator sinusoidal ?

Oscilatoare in trei puncte, amplificator cu tranzistor

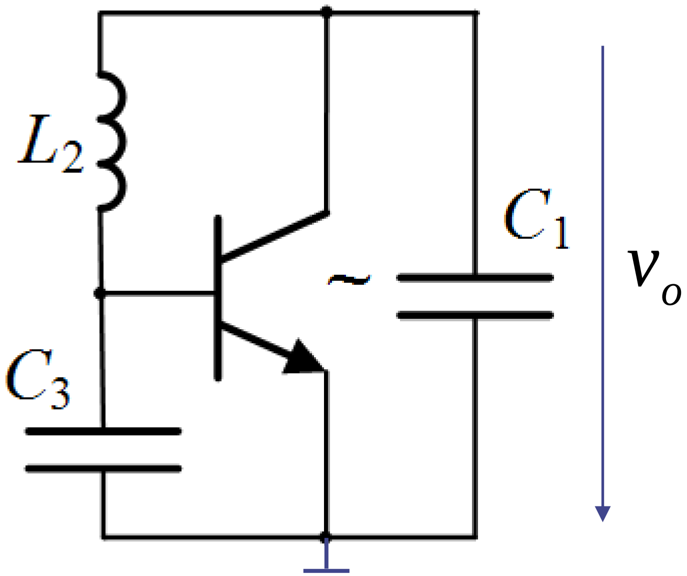


*Schema de principiu, pentru **variatii de semnal***

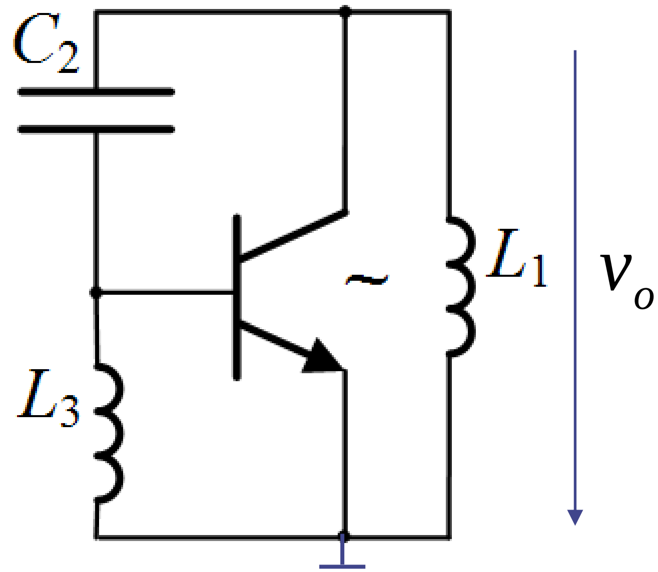
Amplificatorul de baza este inversor (EC), asadar divizorul Z_2, Z_3 trebuie sa introduca defazaj de -180 grade; Z_2, Z_3 vor fi de semn opus (de natura diferita)

Z_3 si Z_1 de acelasi tip (apar conectate in serie) pentru a rezulta un circuit rezonant paralel *LC* intre colector si baza

Schema echivalenta pentru variatii a oscilatoarelor in trei puncte



Colpitts



Hartley

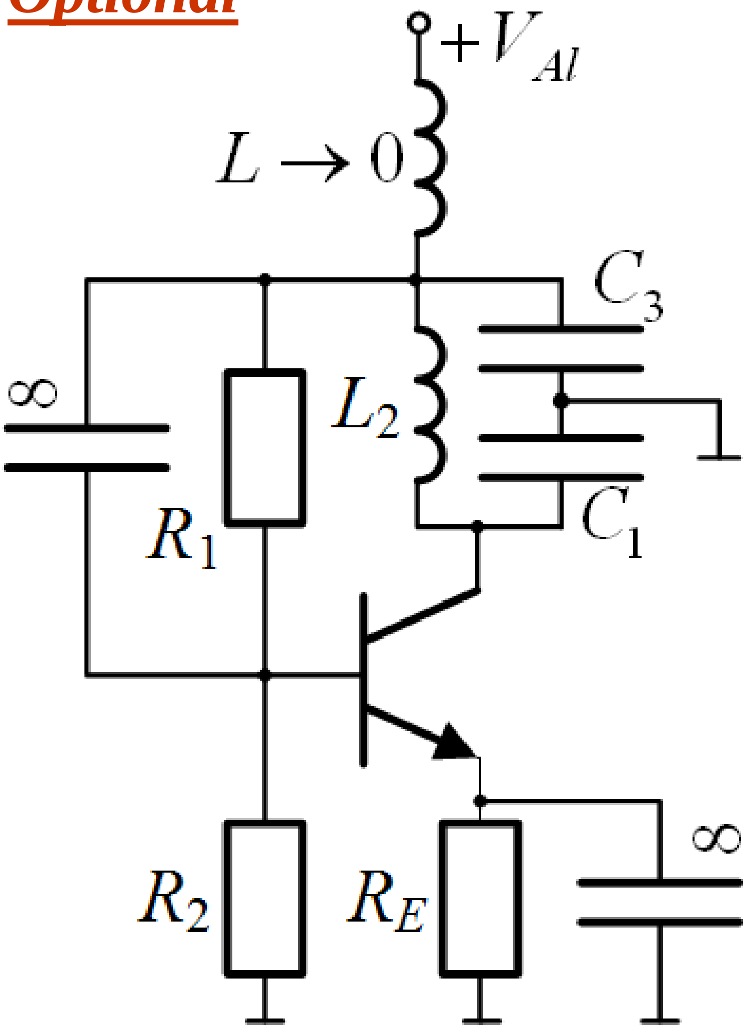
$$C = \frac{C_1 C_3}{C_1 + C_3}$$

$$L = L_1 + L_3$$

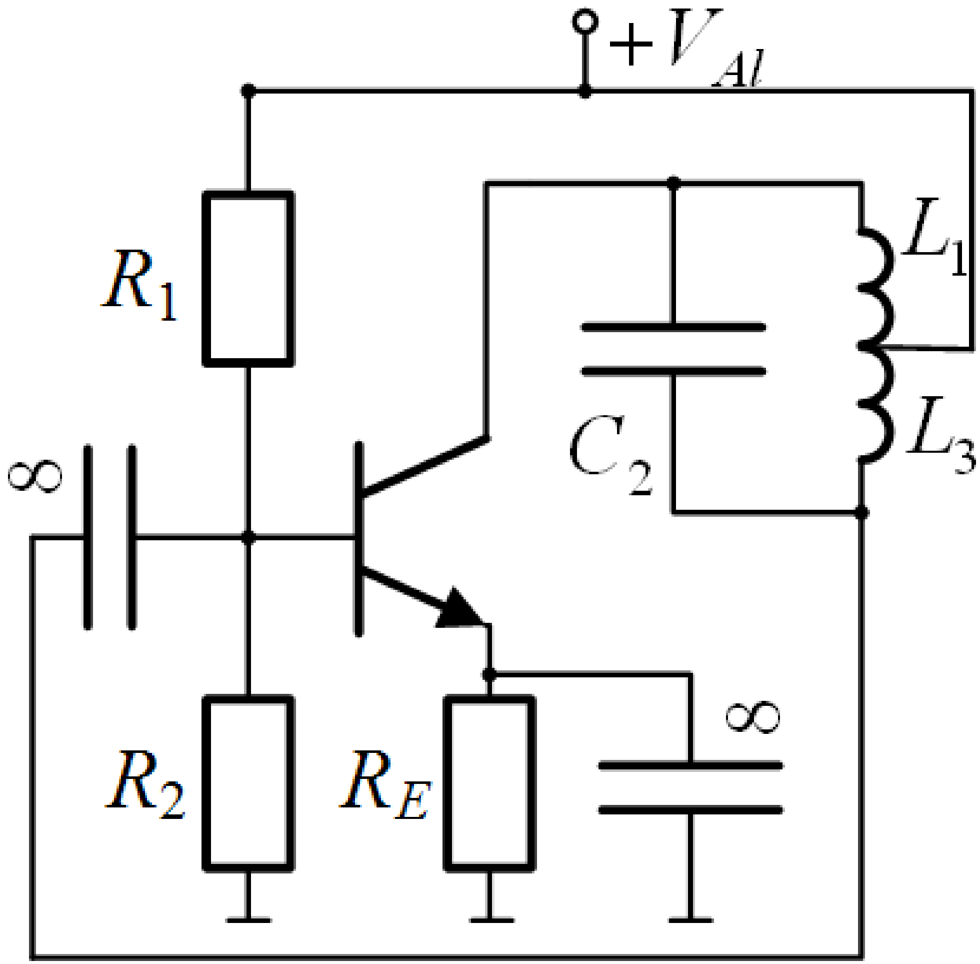
$$f_0 = \frac{1}{2\pi\sqrt{L_2 C}}$$

$$f_0 = \frac{1}{2\pi\sqrt{L C_2}}$$

Optional



Colpitts



Hartley